



Saskatchewan
Agriculture

Soils and Crops
Branch

Sulphur Fertilization in Crop Production

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Introduction

Sulphur (S) has been known for many years as an essential plant nutrient, but reports of deficiencies have become more common in recent years. Many crops remove almost as much sulphur as phosphorus from the soil, although total amounts of soil sulphur are often less than half of soil phosphorus.

Reasons for Increasing Sulphur Deficiencies

There are several reasons for the increasing occurrences of sulphur (S) deficiencies:

- o the increasing acreage of crops with higher S requirements and greater sensitivity to S deficiencies (canola, certain legumes).
 - o increased use of high-analysis N, P, and K fertilizers containing little or no S.
 - o stricter air pollution control laws, thus decreasing the deposition of S compounds on soils.
 - o decreased use of S-containing fungicides and insecticides.
 - o leaching of sulphate below the root zone. Most of the plant-available S is not tightly held in the soil, allowing it to move with the soil water.
 - o decreasing levels of organic matter in most soils.
- o the removal of large amounts of S by more stubble cropping and high-yielding crops.



Sulphur deficiency in early and late stages of canola growth



Areas of Sulphur Deficient Soils in Saskatchewan

Approximately one million hectares of crop land in Saskatchewan have insufficient available sulphur for maximum yields of sensitive crops such as canola.

Large areas of sulphur deficient soils exist in the northern agricultural areas of Saskatchewan (Figure 1). A large proportion of the deficient soils are coarse-textured (sandy) types in the Gray-Black and Gray soil zones (Figure 2). Sulphur deficiency in medium to fine-textured soils is fairly common in the Gray soil zone, but occurs less frequently in the Black, Dark Brown and Brown soils. However, increasing occurrences of sulphur deficiency in canola, alfalfa and clover have been observed in the Black and Thin Black soil zones.

Some of the most severe cases of sulphur deficiency have occurred where canola has been seeded on sandy soils in the Gray-Black and Gray soil zones on fields recently broken out of alfalfa or grass-alfalfa, especially if the forage crop was not adequately fertilized with sulphur.

According to soil test results of recent years some soils in the Dark Brown and Brown soil zones have low supplies of available S. However, crop response to sulphur fertilization may be infrequent on these soils. In comparison to Gray soils, Brown soils often have larger amounts of available S in

the root zone, but below the 24 inch sampling depth. Therefore, low testing clay or clay loam soils in the Brown and Dark Brown soil zones merit test strips only for sulphur application.

Soil Sulphur

Sulphur occurs in the soil in both organic and inorganic forms. Most of the sulphur in soils that are likely to be S deficient is in organic combination. The **organic sulphur** must undergo microbial decomposition to a soluble inorganic form before it is available to plants. This breakdown process is slow and usually does not supply enough sulphur for plant growth during a growing season if available levels are low at seeding time. The rate of breakdown of organic matter and mineralization of organic sulphur is influenced by such factors as moisture, temperature, soil pH and the presence of plants.

Inorganic sulphur occurs primarily as water soluble sulphates of calcium, magnesium and sodium. Plant available sulphur in the soil includes the soluble inorganic sulphate in the soil solution, the sulphate adsorbed to clay and that portion of the organic sulphur that is mineralized and oxidized to the sulphate form during the growing season. Soils which are saline or contain gypsum (calcium sulphate) have levels of available S which exceed plant requirements.

Figure 1
Areas of
Sulphur Deficient
Soils in Saskatchewan

Legend

1. Brown soils
2. Dark Brown soils
3. Thin Black soils
4. Thick Black and Gray-Black soils
5. Gray (wooded) soils
6. Gray soils and muskeg

Area with most frequent occurrences of sulphur deficient soils in Saskatchewan

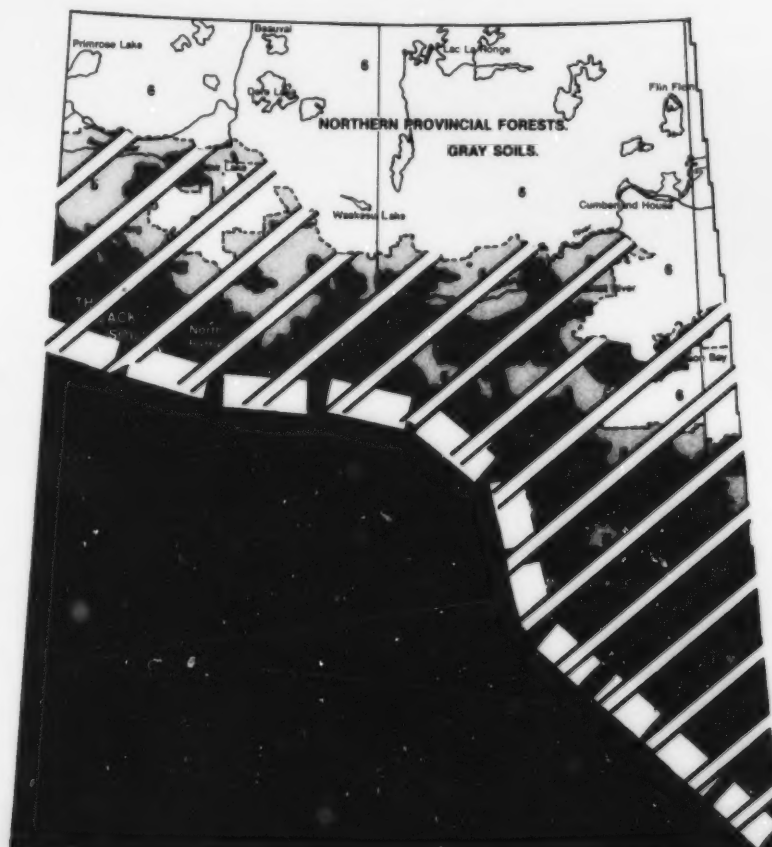
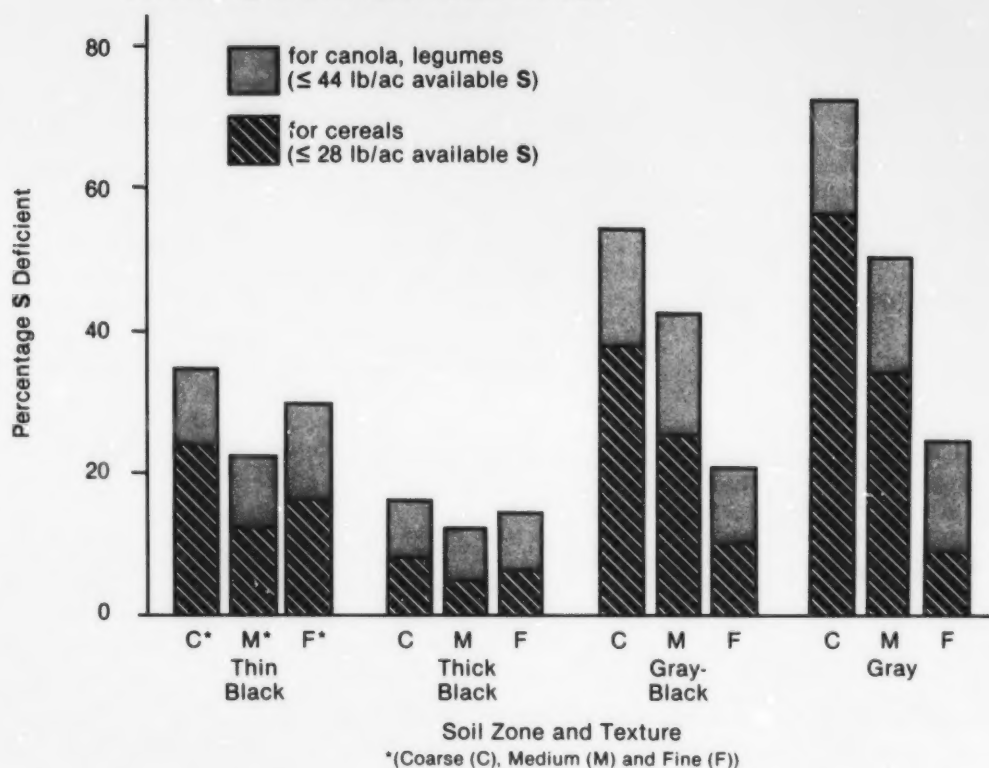


Figure 2. Influence of Soil Type on
Percentage of Fields Deficient in Sulphur
(According to Soil Test, 4 year average)



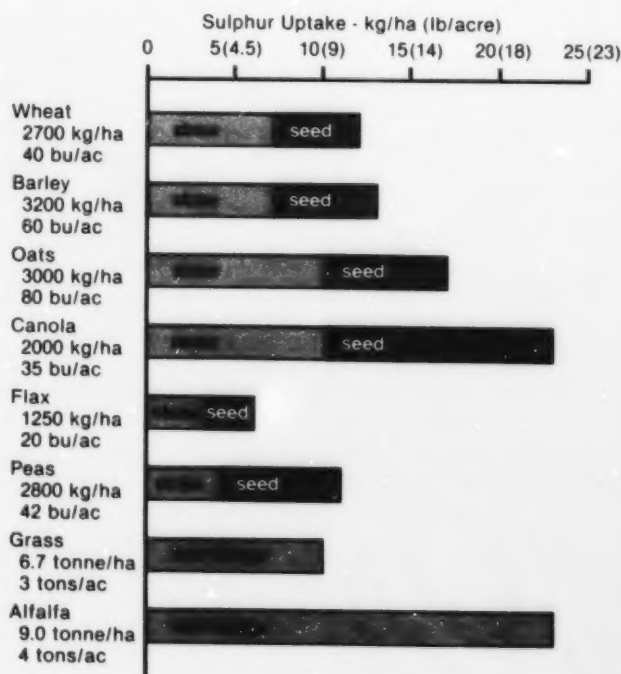
Sulphur Requirements of Crops

Forage legumes such as alfalfa and clovers require relatively large amounts of sulphur for high production. (See Figure 3). These crops are high in protein, of which sulphur is an important constituent. Where large yields of forage are harvested a substantial amount of sulphur is removed from the soil annually. Furthermore, these legumes are dependent on adequate available sulphur to maintain a high level of nitrogen fixation.

Grasses generally require less sulphur than legumes and may grow quite well on soils which produced low yields of alfalfa or clover.

Of the crops grown for seed, certain oilseeds, in particular canola, require large amounts of sulphur because they are rich in protein. Wheat, barley, sunflowers, peas, lentils and fababeans are intermediate in their sulphur requirements, while flax and buckwheat take up small amounts. Most crops contain approximately as much sulphur as phosphorus in the total plant.

Figure 3. Uptake of Sulphur by Crops*



*These are average values. Uptake varies with soil and climatic conditions.

Sensitivity of Crops to Sulphur Deficiency

Canola and alfalfa are very sensitive to sulphur deficiency. On very low sulphur soils virtually complete failures of these crops can occur without the application of appropriate sulphur fertilizers. Furthermore, on such soils the application of nitrogen fertilizers without added sulphur is seldom effective or economical, and may even depress yields.

Sulphur Deficiency Symptoms

General

- o plant growth often restricted-plants have short and/or spindly stalks or stems.
- o growth rate is retarded and maturity delayed.
- o on most plants, young leaves are pale green to yellow in color, progressively changing to yellow-white in cases of severe deficiency. This yellowing of the leaves is often confused with nitrogen deficiency. In sulphur deficiency, the younger, upper leaves are affected first. In nitrogen deficiency the older, lower leaves show the yellowing symptom first.
- o on legumes, nodulation is frequently reduced.

Canola

Restricted growth results in stunting or tall spindly growth. Leaves tend to be more erect, especially on the upper parts of the plant. In initial stages and with moderate sulphur deficiency there is a general yellowing of the younger leaves, gradually progressing to older leaves. Leaves may cup inwards and develop pink or reddish color on underside and this may later extend to the upper leaf surfaces. The red coloration on the leaves may turn to purple as plant growth progresses under sulphur deficiency stress. Leaves tend to be narrower than on normal plants.

Flowering is delayed and prolonged and flowers may be pale to whitish. Pod set is reduced and pods tend to be thin and short, decreasing in number toward the top of the plant. Plants tend to stand erect because pods are poorly filled and seeds are small. Maturity is delayed.

Alfalfa

New growth is pale yellow-green and tillering is reduced. Individual leaflets tend to be erect and reddening may develop in the stem.

Wheat and Barley

General yellowing of leaves, starting with the youngest. As plants develop, younger tillers may stand more erect. Older leaves tend to remain green.

Flax

First, general yellowing of top of plant. Leaves in this area tend to be pressed to the main stem, giving an erect appearance to the stems. Yellow tops gradually extend down the plant, with leaves, stems and basal shoots turning yellow in extreme cases. Leaf size is reduced.

Field Peas

Upper part of the plant is affected first. Leaves may turn a pale yellowish-green with reddening of stems towards top of plant. Petioles of sulphur deficient plants are generally reddish, leaflets are small, and the length of the stem internodes may be reduced.

Sunflower

Pale green or yellowish plant starting with upper, younger portion. Growing point may show most obvious effects - a very pale, creamy colored rosette formed by uppermost leaves and flowers. Reduction in plant height.

Potatoes

General yellowing of the leaves and considerable reddening of the stems. Younger leaves tend to curl inward.

Corn

Yellowing between the veins in the leaves especially on younger, upper leaves. As deficiency progresses, reducing may develop in stems and leaves, starting at the margins of leaves. Oldest leaves remain green.

Crop Response to Applied Sulphur

On soils low in available sulphur the application of the appropriate form of sulphur fertilizers along with other required nutrients usually produces large yield increases in sulphur sensitive crops. Yields of alfalfa have been increased by more than 3,000 kg/ha (1.5 tons/acre) in northern Saskatchewan. Yield increases of canola have exceeded 1000 kg/ha (18 bu/ac). Sulphur fertilization has also produced earlier and more uniform maturity and higher oil and protein contents. Substantial increases in yields of wheat and barley have also been obtained on soils low in available S. See Tables 1 and 2.

Nutrient Balance

Maximum response to sulphur fertilizers cannot be attained without adequate quantities of other nutrients in the soil. In particular, since both N and S are required for protein synthesis, a shortage of either nutrient affects the crops use of the other in plant growth. **By applying high rates of nitrogen fertilizer to soils low in sulphur, N to S ratios may be raised to excessive levels, which may induce or intensify sulphur deficiency in crops.** The application of high rates of nitrogen fertilizer without sulphur on canola grown on S deficient soils generally produces little or no yield increase and may reduce yields below the unfertilized levels (Table 2).

TABLE 1. DIRECT AND RESIDUAL EFFECTS OF SULPHATE-SULPHUR ON YIELDS OF WHEAT AND ALFALFA GROWN ON A GRAY SOIL VERY DEFICIENT IN AVAILABLE SULPHUR

Fertilizer Treatment	Wheat on Fallow	Alfalfa (first year)	Alfalfa (residual)
-----kg per hectare-----			
O	1680	3120	5450
N	1660	1950	4660
S	2020	5470	7400
NS	2330	7480	8210
NPS	2320	7670	7170

TABLE 2. EFFECT OF NITROGEN AND SULPHATE-SULPHUR FERTILIZERS ON YIELDS OF CANOLA AND BARLEY ON GRAY SOILS VERY DEFICIENT IN AVAILABLE SULPHUR

Fertilizer Applied	Canola N.W. Saskatchewan kg/ha (bu/ac)	Barley N. Alberta
O	700 (13)	1740 (33)
NPK	690 (12)	1370 (26)
PKS ₁	980 (18)	2290 (44)
NPKS ₁	1780 (32)	3990 (76)
NPKS ₂	1880 (34)	3410 (65)
S ₁ =	25 kg/ha (23 lb/ac)	22 kg/ha (20 lb/ac)
S ₂ =	50 kg/ha (45 lb/ac)	56 kg/ha (50 lb/ac)

Soil and Plant Tissue Testing for Sulphur

Sulphur fertilizer application should be based on a soil or plant tissue test. Sulphur deficiencies are not as widespread or predictable as nitrogen or phosphorus, and therefore general applications of sulphur are not recommended, except for certain soil types.

On fields with variable topography, the lowest amounts of available S usually are found on the upland or sandy areas where there is less organic matter and where more leaching and erosion have occurred than in other areas of the field. If a field contains areas of both upland or sandy soils and depressions, these should be sampled separately. A few subsamples from depressional or saline areas may mask sulphur deficiencies in other parts of a field.

Sulphates move readily with soil water. Therefore, sampling to a depth of 60 cm (2 ft.) is recommended for a reliable test. Samples should be air-dried as quickly as possible.

Sometimes the available sulphur level is low in the surface soil and sulphur deficiency symptoms may appear on early growth. If sulphates are present in the subsoil, these symptoms may disappear later as roots develop and absorb sulphur from lower depths. When surface soil is very low in available S but substantial amounts are present in the subsoil, it may be beneficial to apply a moderate rate of sulphur to ensure adequate S nutrition of the crop in early stages of growth.

When soil tests show available S in the medium range where occasional responses to S are expected, adding a soluble sulphate fertilizer for canola is recommended when aiming for high yield and quality.

Plant tissue testing is also a useful method for diagnosing sulphur deficiency in a growing crop, particularly for canola and legumes. Sampling should be done as early as possible, preferably at the rosette stage of canola and at similar early stages of other crops. This allows corrective application of sulphur fertilizer to be made early enough to allow for maximum uptake and utilization by the crop. Plant sampling should not be relied on as the only measure of sulphur status but it can be a valuable compliment to soil testing. Instructions for plant tissue sampling can be obtained from the soil testing laboratory.

Sulphur Fertilizer Sources

There are three general types of sulphur fertilizers:

1. Fertilizers containing elemental S - these may contain elemental S only or combinations of elemental sulphur with other nutrients. **Elemental S cannot be directly used by plants but must be**

converted by soil microorganisms to the sulphate form. Examples - Degrasul (0-0-0-90), Urea sulphur (36-0-0-20).

2. Fertilizers containing sulphur only as sulphate - these fertilizers contain sulphur in combination with other nutrients. Most are very soluble and the sulphur can be used by plants immediately upon application. Example - ammonium sulphate (21-0-0-24).

3. Fertilizers containing sulphur as sulphates and/or reduced forms - in these fertilizers a portion of the sulphur is in a readily available form but the remainder must be oxidized in the soil to sulphate form. Example - ammonium thiosulphate (12-0-0-26).

Sulphur fertilizers are sold as solids (granules, crystals or prills), liquids, and suspensions. Table 3 lists the major sulphur-containing fertilizers with their composition and properties.

Effectiveness of Elemental and Sulphate Fertilizers

Most of the fertilizers containing sulphur in the sulphate form are immediately available to crops. **Where sulphur is required for the current crop, a sulphate containing fertilizer should be used.** This form of sulphur, however, is subject to leaching losses, and therefore the application of excessive rates should be avoided.

Elemental S fertilizers applied in the spring of the crop year, may not oxidize to sulphate sufficiently or early enough during the growing season to supply the needs of the crop. Studies in Saskatchewan have shown that these fertilizers often require a year or more to change over to the plant-available form. Rate of oxidation of elemental S is closely related to the particle size of the particular product and the length of time the fertilizer has been in contact with the soil. The smaller the particle size and the more thoroughly it is mixed in the soil, the more rapid, in general, will be the change to the sulphate form and the greater will be the crop uptake and response. In general, elemental S should be applied at least one year prior to growing the crop for which the S is required.

Elemental sulphur fertilizers release available S relatively slowly so they are less subject than sulphates to leaching losses. Such fertilizers generally produce small yield increases of established legumes such as alfalfa, or canola in the year of application, but yields of crops may be substantially increased in subsequent years, after the residual S has changed to an available form.

Table 3. The Major Sulphur Fertilizers and Their Characteristics

Name	Nutrient* Percentage	Physical Properties	Comments
Ammonium Sulphate	21-0-0-24	—Crystalline solid particles. —May segregate in blends with other fertilizers.	—Applied prior to or after seeding. —Contains sulphur in a readily available form.
Urea Ammonium Sulphate	34-0-0-11	—Prilled, granular and crystalline solid particles. —1:1 ratio of urea and ammonium sulphate.	—Applied prior to or after seeding. —Contains sulphur in a readily available form.
Urea Sulphur	36-0-0-20	—Solid, granular. —Granule contains urea and elemental sulphur.	—All S is in the elemental form, not immediately available to plants.
Ammonium Phosphate Sulphate	16-20-0-14	—Solid, granular.	—Sulphur is in a readily available (sulphate) form.
Ammonium Thiosulphate	12-0-0-26	—Liquid. —Non-corrosive. —Specific gravity 1.325 kg/L. —Can be mixed with all standard fertilizer liquids which are non-acid.	—Apply at rates recommended for sulphate sulphur. —Applied prior to or after seeding. —Can be applied with irrigation water.
Urea Ammonium Sulphate Solution	20-0-0-5	—Liquid. —75% of the N in the fertilizer is urea and 25% is ammonium sulphate. —Specific gravity is 1.24 kg/L.	—Can be applied prior to or after seeding. —Contains S in a readily available form.
Gypsum	0-0-0-17	—Solid. —Moderately soluble.	—Availability depends on soil type, but is often not readily available.
Elemental Sulphur	0-0-0-90S to 0-0-0-99S	—Can be blended with most dry fertilizers except ammonium nitrate.	—Must be oxidized to sulphate before the plant can use it. —Apply at least one year in advance of use by crop.

*refers to percent N, P₂O₅, K₂O and S

TABLE 4. EFFECT OF TIME OF BROADCASTING GRANULAR SULPHATE-SULPHUR FERTILIZER FOR CANOLA

Cultivar	Time Sulphur Applied	2 Year Average Seed Yield Increase Over Check		% Oil in Seed
		Kg/ha	(bu/ac)	
Regent	at seeding	393	(7.1)	44.1
	7 days after seeding	469	(8.4)	44.3
	14 days after seeding	374	(6.7)	43.6
	28 days after seeding	394	(7.1)	43.6
	42 days after seeding	310	(5.6)	43.4
Candle	at seeding	322	(5.8)	41.7
	7 days after seeding	314	(5.7)	42.6
	14 days after seeding	340	(6.1)	43.2
	28 days after seeding	302	(5.4)	42.7
	42 days after seeding	204	(3.7)	43.0

Rates and Methods of Sulphur Fertilizer Application

Recommended rates of sulphur application vary with the crop and the soil test level of available sulphur. The maximum rate recommended for oilseeds is 33 kg/ha (30 lb/ac) of sulphate-S; the maximum rate for cereals is 22 kg/ha (20 lb/ac).

Broadcasting

Except for leaching, sulphur fertilizers are not subject to loss processes such as those that occur with ammonium and nitrate-N fertilizers, and therefore sulphates as well as elemental S forms can be broadcast. To speed up the oxidization of elemental sulphur fertilizers, broadcasting and incorporation is more effective than banding. For established forages, sulphate fertilizers should be broadcast in late fall or early spring.

Banding

For **cereals**, up to 110 kg/ha (100 lb/ac) of ammonium phosphate sulphate (16-20-0-14) can be placed with the seed. Fertilizers like urea ammonium sulphate (34-0-0-11) and ammonium sulphate (21-0-0-24) should be banded away from the seed to prevent seedling injury.

For **canola, mustard and flax**, up to 85 kg/ha (75 lb/ac) of 16-20-0-14 can be applied with the seed. To avoid harmful effects on germination of canola and small seeded forage crops, higher rates of sulphur should be banded away from the seed at or before planting or broadcast and incorporated before planting.

Time of Application of Sulphur Fertilizers

Soluble sulphate fertilizers can be applied in late fall or in spring before seeding or at time of seeding, preferably by banding. Generally, the closer to seeding that the sulphur is applied the less potential for leaching losses. If a sulphur deficiency is diagnosed in canola after crop emergence, a soluble sulphate fertilizer can be broadcast to correct the problem. Such applications should be made as soon as possible, as the effectiveness of broadcast sulphur will depend on rainfall to move the fertilizer into the soil. However, in field studies under favorable moisture conditions in northern Saskatchewan,

responses of canola to sulphate fertilizers applied up to four weeks after seeding were equal to those from fertilizers applied at time of seeding (Table 4).

Elemental S fertilizers should be applied at least one year before seeding of a crop. The soil should be tested near the time of seeding to assess the level of available sulphate. When elemental sulphur fertilizer is broadcast on an established legume or other forage stand, significant response may not occur until the following season. **Further experimentation is required before elemental sulphur can be recommended to correct sulphur deficiencies in the year of application.**

Summary

Well drained sandy soils and gray soils are frequently sulphur deficient. Sulphur deficiency may occur in many other soils and in any area of the province. Because of this a soil test is recommended to establish the available sulphur status of your fields.

Crops vary greatly in their sulphur requirements. Canola, mustard, and forages containing a legume component have a higher sulphur requirement than cereal grains or flax.

Sulphur deficiencies are more likely to occur in crops having a high sulphur requirement. These crops also have a greater tendency to deplete the sulphur for subsequent crops. This is particularly true following breaking of a perennial forage stand.

Sulphur fertilizer recommendations are based on sulphur being applied in the sulphate (SO₄) form since it is the only form readily available to plants. Some nitrogen and phosphorous fertilizers contain sulphate sulphur; for example, 21-0-0-24 and 16-20-0-14.

Sulphur in the elemental form is not available to plants until oxidized to the sulphate form.

Oxidation of sulphur requires time and depends on soil temperature and moisture, size of sulphur granules and the rate at which granules break down in the soil. Recent research has found that sulphur from these products does not become available in sufficient quantities to meet crop requirements in the year of application. Therefore, they are not recommended to be applied on soils with a low available sulphur content where the crops would require the applied sulphur to be available in the immediate year of application.



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